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JOHN B. WATSON, JOHNS HOPKINS UNIVERSITY (*J. of Exp. Psych.*)

JAMES R. ANGELL, UNIVERSITY OF CHICAGO (*Monographs*) AND

MADISON BENTLEY, UNIVERSITY OF ILLINOIS (*Index*)

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THE
PSYCHOLOGICAL BULLETIN

GENERAL REVIEWS AND SUMMARIES

TROPISMS AND INSTINCTIVE ACTIVITIES

BY HARRY BEAL TORREY

Reed College

1. *General*.—With the exception of four brief chapters on their origin, geographical distribution, polymorphism and parthenogenesis, Buttlet-Reepen's (6) book on the bees is concerned, as its title indicates, primarily with their modes of life and activities. The fifth chapter is devoted to the evolution of the bee colony. A discussion of comb structure and bee hives is followed by a chapter on various phases of the life history, and special chapters on the collection of pollen and on the manipulation of the wax plates secreted by the abdominal segments. Of especial interest to the psychologist are chapters on the senses, instincts, and psychology of the bees. A good working bibliography is appended.

Clausen and Goodspeed (9) develop a concept of hereditary reaction-systems, an extension of Mendelian concepts suggested by their studies of *Nicotiana* hybrids.

Fenn (13) finds a close analogy in alkaline gelatine to Osterhout's experiments on the electrical resistance of *Laminaria*, if it is assumed that the effect of time in the *Laminaria* experiments is to increase the concentrations of the salts in the cells of the tissue.

Holmes' (16) *Studies in Animal Behavior* will be reviewed at length in another place.

Neal (28) discusses the opposing claims of vitalism and mechanism as bases for the interpretation of individuality in organisms. He concludes that "individuality (personality) is a phenomenon not determined by the perceptual conditions only, but requiring to account for it the agency of a non-perceptual agent."

The results of experiments by Pearl (45, 46) on the effect of inhaled alcohol upon the domestic fowl and especially upon the progeny of treated individuals are especially interesting in that they apparently contradict the results of Stockard for guinea pigs. For twelve characters the offspring of treated parents either equal or excel the controls in ten. This result accords with the conclusions of Elderton and Pearson for workingmen's population and Nice's experiments with mice. Pearl attempts to reconcile his results with those of Stockard by assuming a differential effect of alcohol on the germ cells of any individual, the most vigorous cells, those least affected, tending most frequently to form the zygotes; also a difference in mean absolute vigor in the germ cells of different species, the same dosage that completely incapacitates the germ cells of one species failing to affect to a measurable degree some proportion of the germ cells of another, thus leaving them free to form normal zygotes. Caution is urged against transferring conclusions from one sort of animal to another, for instance from guinea pigs (Stockard) to man.

2. *Tropisms and Allied Phenomena*.—As a result of his experiments on the rheotaxis of *Asellus*, Allee (2) finds a suggestive relation between the chemical activity of certain cations and their effect on rheotaxis of isopods. Potassium is the most effective in increasing the positive reaction in *Asellus*, and the most stimulating. Its depressive effect is toxic, in contradistinction to the depressing effect of calcium which depresses rheotaxis long before toxic symptoms appear. There is a marked antagonism between potassium and calcium chlorides in their effect upon rheotaxis. Acids, alkalis and cane sugar, in the concentrations used, decrease positive reactions. Measured by susceptibility to sodium cyanide, the rate of metabolism of *Asellus* is increased by potassium chloride, which increases positive rheotaxis, and decreased by calcium chloride, which decreases positive rheotaxis. The rheotactic reaction of *Asellus* can be controlled by varying the oxygen and carbon dioxide tension within the limits found in the two classes of habitats.

Allee (3) concludes that the different rheotactic reactions exhibited by *A. communis* from certain pond and stream mores respectively are not due to differences in the salt content of the water from the two localities.

Buddenbrock (5) attacks what he regards as the "tropism theory of Jacques Loeb" by a series of arguments and citations of fact not unfamiliar to controversialists in this field.

According to Cole (10), *Drosophila ampelophila*, when creeping, reacts negatively to gravity, to a centrifugal force equal to or slightly greater than gravity, and to air currents without regard to other stimuli. This is believed to be determined by a muscle sense, the effective stimuli being due to tensions in the legs and received by the sensory nerves of the leg muscles.

Dolley (12) concludes from his experiments on *Vanessa antiopa* that the orientation of this butterfly is not wholly dependent upon the relative intensity of light on the two eyes. He bases this conclusion on various observed facts which indicate also that the path in the nervous system along which the impulses travel is not permanently fixed.

Hess (15) reports upon the accommodation reaction and mechanism in alciopid eyes, the sensitiveness to light of the ambulacra of *Astropectinids* and measurements of the motor sensitiveness of various animals to light. From the last, the author concludes that various animals are color blind, including the butterfly finch which is brilliantly ornamented on breast and tail with blue. Other experiments, he believes, refute the assertion that heliotropism of plants and animals is identical. His criterion here is questionable—namely, the region of the spectrum to which the organisms respond.

Loeb and Wasteneys (21) have reexamined the applicability of the Bunsen-Roscoe law—whereby the heliotropic effect is determined by the product of the intensity into the duration of illumination—to the phenomena of animal heliotropism. Using a method differing somewhat from those previously published by Loeb and Ewald, they obtain results that harmonize with the former conclusions of the authors just mentioned, namely, that the Bunsen-Roscoe law is the correct expression of the influence of light upon the heliotropic reactions of *Eudendrium*.

According to the observations of Mast and Lashley (22) *Paramaecium*, *Stentor*, and *Spirostomum* do not produce a continuous feeding cone. In rotifers the feeding cone appears to be continuous. In none of these cases does it appear to be of appreciable value in providing a warning of unfavorable environment ahead.

Commenting on a recent paper by Mast, Moore (24) calls attention to a previous paper in which it is pointed out that the orientation of *Gonium* in a galvanic current is due to differences in the activity of the individual flagella of each cell. Any analysis of the phenomena of orientation in *Gonium* must, he believes, include a consideration of this fact.

Moore and Kellogg (25) find that the constant current produces in *Lumbricus terrestris* an increased tension of the longitudinal muscles on the kathodal side of the worm, throwing the latter into the form of a U open toward the kathode. This result is in harmony with observations on various other organisms and accords with Loeb's theory of galvanotropism.

Olmstead (30) finds that *Planaria maculata* varies its response to gravity according to its previous experience with light and food. Unfed individuals which have been in the light are positively geotropic when placed in the dark. After several days, they become indifferent to gravity. Fed individuals taken from the light, are likewise positively geotropic at first, but negative after two days and indifferent after five days. Individuals in the dark for some time and fed continuously are negatively geotropic. These facts suggest the view that the individuals which are found under rocks, ventral side uppermost, are only those that have been feeding.

Reese (50) observes that when white light from above—or below—strikes the crimson spotted newt, the response is negative, in ordinary temperatures, indifferent in temperatures near 0° C. and 36° C. When light falls from the side, the response, whatever the intensity of the illumination, is positive at ordinary temperatures, inhibited or reversed at temperatures near 0° C. Placed between two lights of different intensities, the newts tend toward the less intense light when the intensities are relatively high, toward the more intense when they are relatively low. The animals react to a beam of light with a diameter greater than 5 cm. thrown on various parts of the body. When the light comes from the side, the response is positive.

Schaeffer (51) concludes, from various experiments, that *Amoeba* (1) "senses small particles of insoluble substances, such as carbon, glass, silicic acid" at a distance; (2) reacts both positively and negatively to tyrosin grains; (3) forms food cups under stimulation by weak solutions of both egg albumin and peptone.

Schaeffer (52) reports a series of experiments on two species of *Amoeba*, noting the feeding reactions of each to carmine, india ink and uric acid grains, and solid egg white.

Schaeffer (53) has supplemented his previous account of the feeding reactions of *Amoeba* by observations on the reactions produced by various isolated and compound proteins.

Schaeffer (54) concludes that beams of light and of darkness are sensed at a distance by *Amoeba*, positively and negatively, in the respective cases; the response varying with circumstances.

Walton (57) finds that light has an activating effect on the ciliary apparatus of *Paramecium caudatum*. The rate of locomotion varied in his experiments from 3 cm. per minute in an intensity of 5.1 candle meters to 8 cm. per minute in an intensity of 1,422 cm. When the intensity was suddenly changed from one extreme to the other, no change in the response of the animal appeared for perhaps two minutes, after which the normal response for the given intensity was gradually reached. Among conjugating individuals the degree of the response was greatly diminished or entirely lacking in about forty per cent. of the cases.

Wenrich (60) finds that some molluscs, such as *Anodonta* and *Pecten* are sensitive to decreases in light intensity only; others (e. g., *Mya*) are sensitive both to increases and decreases; and still others (e. g., *Cumingia*) to neither. Responses are affected by various physiological states. The sensitive areas are always pigmented. The reaction to an increase of light intensity in some cases is a withdrawal of the siphon tube, while reaction to a decrease differs from this in being a closure of the siphonal openings. Evidence is found for the view that the eye of *Pecten* may form an image.

3. *Actinian Behavior*.—Parker (31, 36) describes four effector systems in *Metridium*, the mucous, nematocyst, ciliary and muscular systems. The first three are independent effectors, not controlled by a nervous mechanism. The muscular system shows a variety of conditions. Some muscles are independent effectors; others are activated by nerve impulses. Non-nervous muscular responses are sluggish as compared with nervous muscular responses. Certain well-individualized reflex mechanisms exist.

From experiments Parker (32, 38) concludes that there is a widely diffused nerve net in *Metridium*. Connections are established from ectoderm through mesoglea to endoderm in many places, less readily through the lips than elsewhere. Evidence for a certain degree of specialization in the transmission system, between tentacle and mesenteric muscles, indicates relatively independent transmission-tracts—"a first step in the kind of differentiation so characteristic of the nervous organization in the higher animals."

Experiments on the tentacles of *Condylactis* lead Parker (33, 39) to conclude that the actinian tentacle, in contradistinction to such appendages as those of the arthropods or the vertebrates, contains a complete neuromuscular mechanism by which its responses can be carried out quite independently of the rest of the polyp. The chief

nervous layer appears to be in the ectoderm, the fibers extending predominantly toward the base of the tentacle.

Parker (34, 40) finds that locomotion in actinians, which has no relation to the secondary axis of the column, is accomplished by wavelike movements of the pedal disk mechanically identical with similar movements of snails. It is aided by the secretion of slime from the disk surface. The waves are produced by three sets of muscles which act on fluid filled spaces in the pedal region, producing a slight internal pressure. The entire neuromuscular mechanism necessary to locomotion is contained in the pedal region alone. The oral disk is not essential.

The observations of Parker (35, 41) support the view that an actinian possesses a low degree of organic unity, being organically more nearly a sum of parts than a unit. Though modifications of response to repeated stimulation may be readily induced, they are referable, not to associational processes, but to sensory fatigue, as in the behavior of the oral cilia and the feeding movements of the tentacles. Though *Sagartia* exhibits in its retraction and expansion a well-marked tidal rhythm, and *Metridium* a well-marked nycthemeral rhythm, neither rhythm persists after the removal of its rhythmic stimulus. In no case has an actinian shown evidence of associative capacity.

Parker (37) and Parker and Titus (42) distinguish four types of muscular mechanism in sea anemones. The first is seen in the longitudinal muscle of the acontium, which responds normally to direct stimulation; the second in the circular muscle of the column which seems to be open to direct stimulation and also under nervous control; the third in the longitudinal muscles of the mesenteries, which are controlled primarily by nerves; the fourth in the transverse muscles of the mesenteries, which respond as in a true reflex when tentacles or lips are stimulated by food. These action systems are variously combined, often highly coördinated, though the nervous system lacks obvious centralization.

Parker and Titus (43) note thirteen fairly well defined muscles or classes of muscles in *Metridium*, representing four types of organization named in the probable order of their phylogenetic development: independent effectors, simple receptor-effector systems which may respond with or without nervous stimulation; more highly specialized receptor-effector systems which respond only through nervous stimulation; complex receptor-effector systems probably including intermediate elements in the form of a conducting

nerve network. The nervous elements are found in ectoderm, endoderm and mesoglea.

4. *Synchrnal Behavior*.—Allard (1) has observed synchronous flashing of fireflies in Massachusetts. Both flight and flashing seem to depend more or less on atmospheric conditions.

Craig (11) examines critically a number of alleged cases of synchronism in the rhythmic activities of various animals, including synchronous flashing of fireflies and chirping of crickets. He finds no satisfactory evidence save in the last case; and there it is doubtful whether the synchronism is due to accident or influence of environment, or a lock-and-key adaptation by which one cricket stimulates another.

Laurent (20) believes that what had appeared to him to be the synchronous flashing of fireflies was in reality caused by the twitching or sudden lowering or raising of the eyelids.

McDermot (23) fails to note synchronous flashing, as reported for American *Lampyridae* (Morse, 27) in any of the nine species studied, with the possible exception of *Photuris pennsylvanica*, a difficult form to observe accurately.

Morse (27) refers to his observation previously recorded (*Science*, 43, 169) of many fireflies flashing in perfect unison; also to similar observations by Shelford in Borneo and H. C. Bumpus in Massachusetts.

Newman (29) reports observations on the behavior of a large colony of "harvestmen" that suggests a possible explanation for the synchronous flashing of fireflies. Hanging from the under side of an overhanging rock, the individual broke into a curious rhythmic dance at his approach. The same result followed poking the colony with a stick. The rhythm, not perfect at first, became so in a few seconds. It appeared to depend on the close interlocking of the legs of neighboring individuals.

5. *Instinctive Reactions Not Included in 3 and 4*.—Bingham (4) relates two anecdotes of bird dogs who assumed the setting posture on crossing the trail, the one of a snapping turtle, the other of a sluggish land tortoise. On reaching the end of the trail, the dog in each case turned away with indifference from the trail maker.

Goodale (14) describes the behavior of five capons that readily accepted and brooded several chicks each. This they did without first becoming broody, as hens usually do. Three of them clucked much like a hen. One of them attempted to tread a chick at various times, though never observed to do so with hens later con-

fined in the same pen. Though Brown Leghorn hens seldom become broody, and then for a short time only, while Rhode Island Red hens with few exceptions become broody during the first year and make excellent mothers, the Brown Leghorn capons mothered their broods quite as well as the Rhode Island Reds. The author concludes that the brooding instinct of the capon cannot yet be cited as proof of the assumption of a female secondary sexual character by a castrated male.

Langley (19) attempts an interpretation of the coloration of tropical fishes on a strictly objective basis. While undermining many speculative explanations of animal coloration in terms of natural selection, his observations emphasize the common occurrence among animals of attributes of apparent advantage to them.

Moore (26) proposes a method of testing the strength of instincts. The method is an ingenious form of association test, based on ten instinctive tendencies of great practical importance.

The discussion by Rasmussen (47) of current theories of hibernation leads him to the conclusion that they are not only numerous but diverse and inadequate. Though various physiological changes accompanying hibernation are known, the controlling causes of the phenomenon remain uncertain.

P. and N. Rau (49), describe the nuptial swarming of *Colletes compactus*, the nesting and other habits of the solitary bee *Calliopsis nebraskensis* Cfd., and the homing of a leaf cutter, *Megachile brevis* Say.

Shannon (55) contributes an interesting discussion of the migration of various insects along well-marked routes also followed by birds. Among these insects are butterflies, dragonflies, a bumble bee, deer flies, flower flies (*Eristalis* and *Syrphus*). Insect-eating birds begin their migration early along with dragon flies. This coincidence suggests that they may follow their insect food southward. Conclusive data are wanting.

According to Weese (59) *P. modestum* reacts to air evaporation with an optimum of 1.5-3 c.c. per hour; to air temperature with an optimum of 30° when the evaporation rate is 3 c.c. per hour; and most definitely of all to substratum temperature with an optimum of 36° to 40°, burrowing taking place at the upper limit.

Young (61) has tested the theory of protective coloration during the last six years by numerous experiments, with crows, hawks, owls, domestic chickens, prairie chickens, grackles, kingbirds and martins as preys, and several kinds of mammals and insects as prey. He

concludes that protective resemblance is effective in protecting motionless animals from attacks by caged birds, but that stillness is probably a more important factor than color in protecting animals from their foes.

6. *Nervous System and Sense Organs.*—It seems clear from the experiments of Cary (7, 8) that the marginal sense organs of *Cassiopea* accelerate regeneration in this medusa, partly through activation of the subumbrella musculature, partly through the influence of the sense organs on general metabolism.

Johnston (17) is strongly inclined to believe, from experiments on three species of turtles, one species of lizard and one alligator, that reptiles possess a general or somatic pallium in which definite sensory and motor areas are to be distinguished. This occupies an area on the dorsal surface of the olfactory bulb; dorsally near the olfactory peduncle and on the lateral border of the hemisphere in its anterior two thirds.

King (18) concludes that rats of very small weight at birth may appear vigorous and healthy during their growth period and in their adult state, which are nevertheless unquestionably subnormal in size of body and central nervous system. These may be produced occasionally in small or medium sized litters. These "runts," lacking in both reproductive vigor and growth capacity, may appear in very large litters, or when the mother is not in good condition during the gestation period.

Rasmussen and Myers (48), after comparing the chromophilous substance of the brain cells of woodchucks killed, respectively, before, during and after hibernation, find no diminution in its amount during hibernation, and no modification in the Nissl granules characteristic of the hibernating state.

Thompson (56) finds no differentiation between the brains of males and females of any caste or stage of *L. flavipes*. What little difference there is between the brains of the different castes and stages is most marked in the optic lobes, the size of these parts being correlated with the development of the compound eyes, hence large in sexual nymphs and adults, greatly reduced in workers and soldiers. The termite brain is very similar in structure to the brain of ants, save as to the mushroom bodies which are simpler and more primitive than in the latter. It is suggested that the frontal gland may have arisen phylogenetically from the median ocellus now lacking in termites.

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SENSORY PHYSIOLOGY OF ANIMALS

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The appearance of papers by Polimanti and Seffrin seems to mark an increasing appreciation of direct methods for the study of sensory physiology of animals. From the standpoint both of accuracy and of economy of the experimenter's time the use of instinctive responses is superior to special training methods. This is particularly true for the determination of thresholds. It is questionable whether dependable results bearing upon differential sensitivity can be obtained from the direct reflexes, although the possibility is well worth the most intensive investigation. The hypothesis that the reflex arc must react as a whole seems to demand some initial differentiation of reaction to any stimuli to which the organ-

ism can form differential habits and data obtained from the study of reflexes in this relation will gain additional value from its bearing upon the theories of objective psychology.

General Studies.—Burnham (8) reviews a number of theories of the origin of nervous integration, particularly the studies of Kappers and Bok and concludes that both in phylogeny and ontogeny the growth and connections of neurones result from the direction of impact of stimulation. The importance of such a conclusion needs not be pointed out. But Burnham disregards the more trustworthy evidence against somatic induction, for predeterminism in the development of the nervous system, and for the permanence of synaptic connections, so that his conclusions seem, to say the least, premature.

Coghill (9) gives detailed descriptions of the early development of the afferent cranial nerves of *Amblystoma*, which contain data wholly incompatible with the foregoing theory of neurobiotaxis. With the anatomical studies he correlates the behavior of the embryos up to the early swimming stage. The threshold to mechanical stimulation is lowest in the region supplied by the spinal nerves, next in the region of the vagus, and highest in that of the trigeminal. The areas were all equally sensitive to acid. Sensitivity to light begins with the initiation of the swimming stage when the optic nerve first connects with the brain and while the retina is still in an embryonic condition. No olfactory reactions were obtained, although the olfactory fibers are far developed and no evidence of function of the auditory sac or of the lateral line system was found, though the nerve supply of the latter is more fully developed than the general cutaneous innervation.

Goebel (11) describes the sleeping movements of a number of plants. They are excited by mechanical, thermal, hygroscopic, and photic stimuli. Summation occurs with both like and unlike stimuli and with repetition adaptation appears. Stimulation of the roots by drying the soil is transmitted to the leaves. The adaptive value of the phenomena is discussed.

Mechanical Sensitivity.—For mechanical stimulation of hollow viscera Hammesfahr (12) introduces pieces of iron, allows recovery from the operation, and then moves the iron about with a powerful magnet. He describes an electrode to be inserted permanently into deep-lying tissues, terminating in a knob over which the skin is closed. The induction current is led through the skin to the electrode and thence to an indifferent electrode on some distant part of the body.

Sensitivity to Chemicals.—Using a membrane behind which solutions could be rapidly changed Löhner (22) tested the sensitivity of the leech to gustatory stimulation. Pure water and physiological salt solution were taken; salt solution, 7 per cent., cane sugar, 5 per cent., quinine, 0.08 per cent., hydrochloric acid, 0.09 per cent., and potassium hydroxide, 0.08 per cent. in solution were rejected.

Changes in respiration were employed by Seffrin (29) as an index to the threshold for olfactory stimulation in the dog. Pure chemicals and extracts of animal tissues were used. To the former the dog tested (a ten-year-old male Spitz) did not react unless the odor was above the human threshold. To dog blood and urine and to extracts of rabbit, roe, and beef flesh he gave marked reactions when no odor was perceptible to the experimenter.

Holt (14) found it possible to stunt the growth of the olfactory bulbs of the rat by defective diet or to enlarge them by exercising the animals. Variations in size were correlated with changes in cell size and not in cell number.

Static and Auditory Sensitivity.—Lehr (21) describes the structure of the Johnston organs in the second joint of the antenna of the beetle, *Dytiscus*, and discusses briefly their possible auditory function, concluding that they are more probably proprioceptors, giving differential sensitivity to the direction of movement of the antennæ.

Nichols (25) gives experimental evidence to show that the reflex control of the flexure of the body of cartilaginous fishes is in part controlled by the action of Reissner's fiber upon sensory cells in the subcommissural organ and central canal of the spinal cord. Bierbaum (5) describes the structure of the internal ear in 26 species of deep-sea fishes. Körner (20) gives a critical review of recent experiments on hearing in fishes, finding no unquestionable evidence that they react to vibrations of the water of a frequency approaching that of sound. He then reports observations of his own on the catfish, in which sounds were produced both above and under water. Contrary to the observations of others he found that the fish never gave any reaction to the sounds.

Vitali (30) considers the function of a sense organ which he has described from the middle ear of the pigeon. Cauterization of the organs leads to an atonia of the wings which may be great enough to prevent flight. He concludes that the organ is stimulated by changes in the density of the air (arguing from structure only) which reflexly affect cerebellar tonus.

Burlet and Kleijn (7) describe the angles made by the otolith

membranes with the chief planes of the skull in the rabbit as determined from reconstructions. Peterson (26) points out the importance of Huter's data on audition in the rat and suggests that the distinction between noise and tone may be due to a lack of resonance in the structure of the cochlea. Muller and Weed (24) find that the falling reflex occurs in the cat after the destruction of the labyrinth and after blinding, but not if both labyrinth and eyes are prevented from functioning. Little interference with the reflex resulted from destruction of the excitable areas of the cortex but the reflex did not appear after total ablation of the cerebrum.

Sensitivity to Light.—Walton (31) reports that 55 per cent. of the paramecia studied by him react to light by swimming at a rate which is directly proportional to the intensity of illumination. In 2 per cent. movement is inhibited by light. Changes in the rate of swimming occurred only after continued exposure to a given light intensity. It does not seem certain that the technique employed precluded changes of temperature as well as of light intensity so that the experiments are not quite convincing.

Mast's study (23) of the relative stimulating effects of different wave-lengths of light upon the reactions of lower organisms marks a real advance in the technique of this problem in that spectral lights of known energy were employed. The limits of sensitivity and the curves of relative stimulating effect of the light throughout the spectrum were determined for a number of protista and for blow-fly larvæ and for the earthworm. The majority of the organisms showed the region of maximum stimulating effect at about $\lambda = 480\mu\mu$ with a range from $\lambda = 420\mu\mu$ to $\lambda = 540\mu\mu$. For a second group the region of maximum effect was at a shorter wave-length, with the spectrum much shortened at the red end. In the distribution of the organisms in these groups there was no correspondence with the phylogenetic relationships.

Bovie (6) finds reactions in amœba and infusoria to light of from $\lambda = 200$ to $\lambda = 125\mu\mu$. These consisted of contractions in amœba and increased, followed by decreased, rate of swimming in infusoria.

Kepner and Taliaferro (19) describe the eyes and ciliated pits of the thigmotactic flatworm, *Prorhynchus*, and compare them with the organs of free-swimming forms. Fasten (10) describes the eye of the larvæ of a parasitic copepod.

Jörschke (18) gives a systematic description of the eyes of 13 species of orthoptera and 6 termites. This is followed by a discus-

sion of the relation of the development of the facette eye to habitat, to light, to the development of the olfactory organs, to rapidity of movement, and to protective coloration.

Polimanti (27) enclosed larvæ of *Bombyx mori* in double-walled glass vessels, so that light had to pass through color filters to reach them. He counted the rate of pulsation of the pulsating vessel. This was determined for total radiation, then with four color filters ranging from violet to red. The rate of pulsation varies with the light intensity. When first placed in the filters the larvæ showed a slight increase in the rate of pulsation, progressively less from violet to red. After two hours in the filtered light all showed a marked reduction in rate of pulsation without any difference corresponding to wave-length. The rather surprising conclusion is that the insects are color-blind. Hess (13) reflected two lights from opposite directions into a cage in which bees were confined and determined their relative stimulating effect from the collection of the insects at one or other end of the cage. He concludes that the threshold of the bee for differences of intensity is as low as that of man. Substituting color papers and filters for the lights he determined the curve of relative stimulating effect to correspond to that of the color-blind man. Accepting Hess's conclusion that bees are color-blind Schwanz (28) seeks to build up a new hypothesis to explain the colors of flowers. The pigments, by their selective absorption of light, act as catalyzers in the formation of protein elements necessary for the formation of seeds.

Wenrich (32) found reactions to changes in light intensity in 13 species of molluscs. Pecten reacted to a moving card when no change in light intensity was involved. This the author interprets as evidence of image-formation. Unequal illumination of different eyes, while not probable, was not eliminated.

Arey has continued the report of his studies of the changes in various retinal elements under the influence of light and heat. The time of adaptation of pigment and of retinal cells and the effects of temperature and of anesthetics upon adaptation were tested for a variety of fishes and for the adult and larval frog. Stimulation of the skin of the frog by light when the eyes were covered did not alter adaptation (1). Migration of pigment in the retina of the snail, *Planorbis*, is induced by temperature and light. Light and cold induce movement toward the optic surface of the retina, darkness and heat the reverse. Excised eyes adapt to light but not to darkness; the latter effect is ascribed to the anesthetic effects of accumu-

lated waste products (3). In the frog the myoids of both red and green rod cells elongate in light and shorten in darkness (2). In an extensive and convincing study of the relation of the optic nerve to photomechanical changes of the retina he has shown the existence of an inhibiting mechanism, probably associated with the autonomic innervation of the eye, which prevents movements of adaptation and, antagonistic to this, efferent fibers within the optic nerve of the cat-fish which indirectly control pigment migration and movements of the rod and cone cells by counteracting the inhibitory action of the autonomic system and so permitting a direct response of the retinal elements to light (4).

Johnson (15, 16, 17) has extended his studies of visual pattern discrimination to include direction and width of striæ. He found the monkey able to distinguish differences of less than 3 per cent. in the width of alternate black and white lines and differences of from 2 to 5 degrees in direction from the horizontal in two fields exposed simultaneously. For the chick differences of 33 or more per cent. in width and of 25 to 40 degrees were necessary for discrimination. Careful tests with the dog indicated that under the most favorable conditions he is unable to distinguish striations on a field. This was true even when corrections for accommodation were made so that it was certain that the striations were focused on the retina.

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HABIT FORMATION AND HIGHER MENTAL CAPACITIES IN ANIMALS

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The year has been above the average in the number and variety of articles having to do with the comparative analysis of learning processes.

Hubbert and Lashley (9) raise the question whether the situation at the end section of the maze may acquire some character from the getting of food which makes it capable of acting like the food in fixing the next preceding section, and, similarly, the second section act in fixing the third, etc.; *i. e.*, whether learning the maze is the formation of a series of secondary, tertiary, and higher conditioned reflexes depending on the getting of food as the primary reflex. Are the errors eliminated in this order? Previous work had indicated that there is no invariable uniform progression of this kind in individual cases. Using the Watson circular maze again, they inquire whether averages will show such an order of elimination. Their results show that the errors due to passing a doorway (all of which should be entered) were much more easily eliminated than those due to making an incorrect turn after passing through the doorway; in fact there was a strong tendency to enter the doorways even without previous training; but the latter (incorrect turn) required about the same number of trials in all portions of the maze, while the former (passing a doorway) gave less trouble at the end than at the beginning of the path. They decide that this order is due to control by gross orientation, which seems to be more definite near the center than at the outside, rather than to any retroactive association.

Carr (2) has given a study of the same problem, order of elimination of errors in the maze. It is based upon results from nine mazes, several of which were of similar character, records for seven of the nine being from Miss Vincent's work. For each maze, he arranged the blind alleys in order of the average number of trials necessary for elimination, beginning with the lowest number, and correlated this order with the order of spatial arrangement in

relation to the food box. Six of the nine mazes show a positive correlation. On the other hand, if the order of final elimination is correlated with the order of the average (beginning with the largest) numbers of times the different alleys are entered during the different stages of learning, a negative correlation is found to be the rule at all stages of learning. The quickness of elimination varies inversely as the attractiveness as measured by the number of entrances, or error distribution. Error distribution is referred to three factors: (a) The tendency of the animals to make exploratory excursions with returns to the starting point, the effects of which are indicated by the fact that the three mazes which show relatively more errors near the end show few returns, and by the fact that, as the tendency to return decreases during learning, so the relative accumulation of errors near the beginning decreases. (b) Such a sensory character of the maze as an olfactory trail tended to prevent errors for a considerable distance from the start, but later the cumulative effects of such influences as curiosity and fear led to digressions and so more errors in the final cul de sacs. (c) The tendency to enter certain alleys is influenced by the peculiarities of the alleys or their relation to the preceding runs made, and, consequently, may vary with changes in the path traversed, brought about during the learning process.

One might suggest that, according to the principle of frequency, the large number of trips through the first part of the maze should lead to early elimination of the errors in that region.

Lashley (14) shows that in comparing the success of two fairly large groups of rats in learning the maze, if we rate them according to the average number of trials required to make one perfect run, we may expect that the difference in the average number of trials required to make a record of three successive errorless runs in the same day will be in the same direction and 1.304 times as large. For statistical comparison of groups there seems to be no advantage in the more prolonged training. It would probably be advisable, for statistical studies, to simplify the problem sufficiently so that a large number of animals may be trained under given conditions.

Gould and Perrin (7), in an investigation of the ability of adults and children to learn the pencil maze, give a critical discussion of the value of the curve of learning in the maze. Mere chance recovery and performance is a serious factor and we should have not only time and error records, but a study of the actual path traversed. Personal peculiarities, not essentially factors of intelligence, exert

an influence. The technique needs standardizing. The adults, all points considered, were superior to the children. The adult curve, during the first ten to fifteen trials, shows more regular and less pronounced steeples than that of the children. There is some correlation between efficiency and relatively slow rate. The good learners average a larger per cent. of all values in the first two trials, and in the first trials are doing more "analyzing, discriminating and memorizing." The children's records were prolonged, mostly by fatigue. Study of drawings made by the subjects showed some tendency towards correlation between accurate drawings and good maze records. The drawings were especially inaccurate as to cul de sacs.

Peterson (19) brings out an interesting point in suggesting "completeness" of response as a selective factor in trial and error learning. As illustrated in the maze, if an animal passes a junction into an alley, there will be a holdover impulse to go into the other path, making the activity incomplete and hesitant. If he finds himself in a blind, this overlapping impulse leads to a return along the other path; if he happens to be in the true path, this continuing tendency gradually dies out. When he reaches the food, all such remaining tendencies disappear. The divided, incomplete attitude tends to prevent the formation of the association in the blinds and strengthens relatively the connections among the successful responses.

Churchill (3) found that goldfish, although they lack a pallium, are able to learn a simple maze consisting of an aquarium cut into three compartments by two partitions with a small opening through each partition. When black bands were put around the openings, the learning became more rapid and reached a more perfect degree, indicating that vision is an important factor. It was indicated that, as the habit became automatic, the control shifted more to kinæsthesia.

In an article (8) which is an unusually interesting extension of his previous work, Hamilton gives a more complete presentation of his only-partially-solvable four-choice method of studying types of trial and error reactions, or "the qualitative aspect of non-adaptive activities." Results are obtained from an inferior class of human subjects, from a baboon and five monkeys, and from several species of rodents. No subject showed a consistent dominance of *A* reactions (attacking the inferentially possible alleys once each, not attacking the inferentially impossible alley). Human

subjects, on the whole, showed more tendency toward *C* reactions (trying all four alleys once each in spatial order) than did the other groups. *D* reactions (more than one attack upon a given alley during a given trial but with intervening attempts at other alleys) and *E* reactions (two or more successive attempts at the same alley during a given trial or persistent avoidance of the correct alley) are caused by inherently primitive reaction type, excitability, distraction and feeble responsiveness. *E* reactions were numerous among the rodents, less so among the monkeys, and least among the humans. We may study the first choice made by a subject at the beginning of each trial and inquire whether it is the same as the last entered (successful) alley of the immediately preceding trial (most recent experience) and what relation it bears to the order of frequency of entrances during all the preceding trials. If this is done, recency is found to play no part, the human subjects giving less than the normal expectation on the basis of chance, the other subjects giving, on the whole, almost exactly a chance result. Frequency of previous entrance, on the other hand, is a very important factor, the first choice corresponding to the most frequent entrance in more trials than the law of chance would indicate with over 80 per cent. of the subjects. In all of the above tests, the correct alley must be constantly changed from trial to trial. If, now, we change the experiment so that a given alley becomes invariably correct and if we make the correct alley that one which in previous trials has shown least attractiveness, then, even in spite of continued opposition of the factor of frequency, relatively few trials are necessary with Hamilton's animals to establish the correct association. Advantage is a much more potent factor than frequency or recency as such.

Yerkes (26) has devised an apparatus which combines the necessary parts so that it may be used for the study of behavior either by the Hamilton quadruple choice method, or by the delayed reaction method of Hunter, or by the Yerkes multiple choice method. He also suggests a series of problems of varying complexity which may be attacked by each method. In other articles (24, 25) Yerkes gives a digest of results which have been obtained by use of his multiple choice method, and which have already been reviewed in this journal.

Performance in the delayed reaction test by a child too young to have a system of sounds so organized as to be used as symbols is of special interest in view of the suggested use of language as an

internal factor in meeting this situation. Hunter (10) carried out such an investigation on a child thirteen to sixteen months of age. Distraction was used during the period of delay, so that bodily orientation was impossible. The child mastered a 10-seconds' delay in the earlier tests and, in the latter part of the experiments, reached a 20-seconds' interval. Many more errors were made by beginning with the left box first than with any other. Control in these tests must be by some intraorganic cues, ideational in function, and Hunter suggests that they are "kinæsthetic sensory ideas," a sort of language which develops earlier than vocal language.

Another investigation by the delayed reaction method is that by Yarbrough (22), using cats as subjects. With part of the animals, the signal or stimulus used was light, with others it was sound. When three boxes were used, the longest delay mastered by the cats was four seconds, although there were indications that, with more training, a longer interval might have been reached. When only two boxes were used, a delay of 16-18 seconds was mastered. Successful reactions were almost invariably controlled by the fact that the subject maintained a constant orientation either of its head or its body or both. No difference was found between the results with sound and those with light.

In the work of Hunter and Yarbrough (11) the T-shaped discrimination box of earlier experiments was used and the motive used was a combination of reward and punishment. Rats were thus trained to turn to the right for handclaps, to the left for silence. Controls showed that they were using the auditory cues. When an electric buzzer was sounded in place of the handclaps, the rats soon made the substitution. When a *c'* tuning fork was sounded in place of handclaps, the habit broke down and the rats could not be trained to respond to the tuning fork. After acquiring the habit of going to the right for handclaps as above, animals were trained to go to the left for buzzer, to the right for silence. It required about twice as long as to learn the original habit,—the handclap habit interfered with the formation of the buzzer habit; and yet, after the latter was acquired, the former was found to be little impaired. The two had become independent units.

A similar investigation from the same laboratory was that by Pearce on interference of visual habits in the rat (17). It was found that rats form visual habits more easily than auditory. It was found almost impossible to establish a second visual habit of opposite character, only one rat succeeding in doing so, although several

times as many trials were given as were required in the original learning.

It has been shown repeatedly that, in mastering a group of sense or nonsense material, it is better to learn the group as a whole rather than to split it into parts; but it is a question whether the whole-part laws hold in learning by the method of trial and error, as in learning a maze, and whether any laws found hold for human and animals alike. These and related questions have been investigated by Pechstein (18). A maze was used, so constructed that it could be learned as a whole or cut, by means of changing gates, into four equivalent sections numbered in order I, II, III, IV, each of which could be learned separately and then the combined whole learned. One maze was made for rats and a similar pencil maze for human subjects. The number of runs and other such conditions were kept the same for both classes of subjects. It was also possible to insert blocks at the end of each section and, by doing so after the subject had passed the point concerned, prevent returns into the preceding sections. By using different groups of subjects, results were obtained as follows. (a) The maze was learned as a whole without interference with returns. (b) The maze was learned as a whole except that returns were prevented from any one section into the preceding sections. (c) The maze was learned in sections in order and the sections then combined into the whole. (d) Section I was learned, then I-II (II not having been learned separately) then I-II-III, then I-II-III-IV. (e) Section IV is learned, then III-IV, then II-III-IV, then I-II-III-IV. (f) Section I was learned, then II, then I-II, then III, then I-II-III, then IV, then I-II-III-IV. For the rats, if we rank these methods of learning according to their efficiency, beginning with the best, the order on the basis of the number of trials required is found to be *f, e, d, a, b, c*. The order on the basis of total time required is *f, e, d, b, c, a*. The order on the basis of number of errors is *f, e, b, d, c, a*. For the human subjects, the order for trials is *f, d, a, b, e, c*. The order for time is *f, b, d, a, e, c*, and that for errors is the same. Comparison of the results from *a* and *b* suggests that retracing and entering of blinds during retracing are mostly useless and raises the question whether we should include retracing in the measurement of maze learning. Learning by the part methods is interfered with by place associations of both temporal and spatial character. On the other hand, learning later sections is facilitated by experience in the earlier—there is a positive transfer. Furthermore, even the first section

involves much less than one fourth the work required for the total maze; and, on the average, each section requires only about one twentieth the learning energy required for the whole maze. Pechstein thinks that methods *d*, *e*, and *f*, reap these advantages of the part process and at the same time meet with varying success the difficulties of place associations with their confusing and emotional effects in a distributed rather than accumulated manner, and, consequently, prove to be the most efficient methods.

The effects of massed *vs.* distributed repetitions were also tested by Pechstein for the human. The whole methods were very injuriously affected by massed effort; there is little chance that the errors of one trial will fail to appear in the following trials, and confusion is cumulative. After elimination of errors is mostly done and the problem is one of mechanization, massed trials are probably of more advantage. The part methods are either much less affected or even improved by massed learning, due to the favorable effect upon setting up connections between the sections.

In connection with the above effects of massed effort on the whole methods, the results of Lashley (15) are of interest. In maze experiments, he studied statistically the identical and diverse errors occurring in the last trials of given practice periods and the first trial of the next practice periods, and compared the results with a similar study of errors in two successive trials in the same practice period. He found a tendency for errors to be repeated from one practice period to the next and still more from trial to trial within the same period. With greater distribution of trials, there is more opportunity for these errors to be dropped.

Mrs. Yerkes (23) compared the performances of stock and inbred rats in learning the maze and in light discrimination. A combination of time and distance or error records was necessary to give an adequate representation of maze learning. In the maze work, the stock rats, on the whole, learned with less effort and greater regularity than the inbred. The inbred rats required a larger number of trials to learn the light discrimination than did the stock rats, but were able to carry the discrimination to smaller differences. The difficulties of the inbred rats seemed to be mainly due to greater timidity and sensitivity to disturbance, emotional instability.

Lashley found one rhesus monkey to be right-handed, another to be slightly left-handed (16). It was possible to modify the use of the hands by training, but whether the effects of this training would be transferred to other acts depended upon complex factors.

Kempf (12, 13) in observational studies of monkeys, finds indications of definite attempts to imitate as well as trial and error learning, and suggests that one monkey showed a "consciousness of self."

Furness (6) attempted to teach monkeys to use language. He succeeded in getting one to speak two words and apparently to attach meaning to them. They learned to match a block to another of the same color, but did not succeed in matching the block to other objects of the same color—they did not generalize.

Sutherland (21) describes an apparatus for studying complex reactions in a dog and indicates the need of closer study of concrete facts rather than general statistical summaries.

Coward (4) watching a blackbird through two seasons, found that the habit of fighting a reflection of himself in a glass persisted in spite of leading to no results. Gulls (5) when they became inland birds, changed their feeding time to the day in adaptation to the locality.

Rabaud (20) treats man in a conventional way as a member of the animal series.

Abbott (1) emphasizes the interaction of function and structure in biology and applies the suggestion to higher mental processes: since there are relations in the world, according to this, we have necessarily developed a structural basis for grasping relations.

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SPECIAL REVIEW

Studies in Animal Behavior. S. J. HOLMES. Boston: Badger, 1916. Pp. 266.

In the present work the author has brought together in readable form many of his own contributions and those of others upon the following topics: evolution of parental care (15 pages), tropisms (three chapters, 70 pages), beginnings of intelligence (19 pages), nature of learning (two chapters, 27 pages), behavior and form (11 pages), behavior of cells (20 pages), death feigning (21 pages), sex behavior (two chapters, 20 pages), and the mind of a monkey (17 pages). The book begins with a twenty-six page chapter on the

history of animal psychology from Aristotle to the beginning of the present experimental movement. Of the fourteen chapters, four are reprints. No great effort has been made to choose related topics or to treat those selected in an exhaustive manner. The book is frankly one of "Studies."

The chapter on parental care traces briefly the elaboration of this instinct from the initial stages when the eggs alone receive attention to the final stage in birds and mammals where the offspring are most carefully tended. Interesting comments are given, after Whitman, indicating the probable origin of the incubation response in birds. This behavior is to be traced back to an earlier ancestral period where the parent remains near the eggs and so protects them. Actually hovering over them is a natural subsequent stage. The warmth even of cold-blooded animals may aid the development of the eggs and later be fixed as a necessity in the warm-blooded animals. Bain is criticized for holding that the pleasure of the embrace is the basis of maternal love. The criticism, I believe, is unjust. Bain is only attempting a description of what is to him the fundamental element present in certain higher animals, notably man. He does not make this the earliest form of maternal and parental behavior nor a form characteristic of all animals.

In the chapters on tropisms the conventional material is presented. In opposition to Loeb's theory, stress is laid upon evidence obtained for *Ranatra*, *Notonectis* and *Orchestia* that the original circus movements which they manifest in response to light finally give place to straight line responses. Such a change would not be expected (Holmes) if the organisms were reflex machines. Holmes and McGraw, and Bancroft are quoted in support of the view that in many cases light acts as a constantly directing stimulus for tropic responses. Numerous illustrations of tropism reversals are given. Mast's hypothesis which refers the phenomenon to reversible chemical action is given as the best attempt at explanation. Inhibition is another possible factor at work.

The author adopts associative learning as a criterion of intelligent behavior. The origins of learning ability are traced and lead into a discussion of the factors that determine habit formation. This is the most carefully written discussion in the book. The pleasure-pain theory and Thorndike's further hypothesis of learning as "an instinct of the neurones" come in for adverse criticism. The author re-states his own view (an extension of Hobhouse's theory) that learning is a case of facilitation and inhibition, of congruous and

incongruous responses. "I have found that in the crayfish stimulation of the antennules, which are important organs of smell, sets up chewing movements of the mouth parts and grasping movements of the small chelae." "Suppose that in the chick the sight-pecking response and the taste-swallowing response are related as the feeding reflexes demonstrably are in the crayfish; the second response would thus tend to reinforce the first, and if this tendency persisted we would have a case of learning by experience" (p. 136). Frequency, recency, and intensity are not explicitly used and one is surprised that there is no mention of the recent important contributions by Carr and Watson. The "beneficial" is selected and the "injurious" is shunned on the basis not of acquired associations, but of inherited organization. "A method of blundering into success instead of attaining it directly, . . . trial and error would be of no service unless the organism were capable of turning to profit its fortunate movement. In order to do this the organism must be provided for the situation by its inherited endowment" (p. 161).

Brief interesting accounts are given of the behavior of cells within the metazoan body, of the influence of behavior in determining the form of the organism, and of sex recognition. The instinct of death feigning in its cataplectic form is traced to a prior thigmotaxis. This is also a possibility in those forms where the musculature is relaxed. Experimental data are quoted in support of this. The final chapter deals with a monkey, Lizzie, *Pithecus sinicus*. The following experiments were performed: (1) A board with an apple on it was placed outside the cage. Lizzie tried to pull in the board; but the effort required was too great. A nail was now driven in the board to serve as a handle. Immediately Lizzie grasped the nail and pulled in the board. This was frequently repeated—although not with great discrimination, because it was done even when the apple was near and not on the board. (2) Observations were made when Lizzie tried to secure food from a bottle and from a Mason jar. (3) A problem box was employed and (4) the monkey was tested for her ability to reach a suspended piece of food by employing a box upon which she might mount. The author, although writing in an anthropomorphic vein, does not credit the subject with general ideas, reasoning or even with the perception of relations. "Possibly more intelligence of the human sort would have been a positive drawback under the conditions of Lizzie's natural environment."

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DISCUSSION

THE JOHNS HOPKINS CIRCULAR MAZE STUDIES

In this paper the three monographs by Hubbert,¹ Basset,² and Ulrich,³ dealing with the reactions of the white rat to the Watson Circular Maze will be discussed. These studies are of importance in contributing to the analysis of the various factors conditioning learning ability in animals below man. References to the details of apparatus, method, number of subjects, criteria of learning, etc. will be omitted in this discussion because of the lack of space.⁴

Hubbert and Basset present valuable data concerning the effect of age and relative brain weight on learning ability. It is unfortunate, in view of this, that the studies did not utilize the statistical methods which are so necessary for a proper interpretation of such comparative data. Our criticism, therefore, is guided by the fact that no measure of the standard error is given when averages are presented and further, that both fail to indicate the degree of reliability that attaches to the differences between the averages involved in their studies.

Hubbert's monograph presents the data for five age groups. It is concluded (on the basis of a comparison of averages) that the young rats (judged by various criteria) learn more readily than the older rats. Because of the great differences between the rats in each age group it is doubtful if the conclusion is valid. For one of the criteria (number of trials necessary to learn) the reviewer has calculated the average deviations. The average number of trials for the 25-day rats was 30.4, average deviation 7.3; for the 65-day rats 30.7 ± 9.3 ; 200-day rats 41.8 ± 21.4 . The average deviation for the 200-day rats is half as large as the average! In this group the mode is 33, the median 32. The average is increased by the presence of six extremely poor rats. Omitting these, the average

¹ Hubbert, Helen B., "The Effect of Age on Habit Formation in the Albino Rat," *Behavior Monographs*, 1915, 2, No. 6.

² Basset, G. C., "Habit Formation in a Strain of Albino Rats of less than Normal Brain Weight," *Behavior Monographs*, 2, 1914, No. 4.

³ Ulrich, J. L., "Distribution of Effort in Learning in the White Rat," *Behavior Monographs*, 1915, 2, No. 5.

⁴ For a factual summary of these monographs see *PSYCHOL. BULL.*, 1915, 12, 301, and 1916, 13, 317. Also see WATSON, J. B., "Behavior, An Introduction to Comparative Psychology," New York, 1914.

becomes 32.6 ± 9.7 while there is little change in the median, *i. e.*, from 32 to 30. The fact that the median is changed so little by this omission while the average is greatly changed, justifies the conclusion that these six rats are not representative 200-day-old rats and may therefore properly be omitted from the group for comparative purposes. Miss Hubbert states (p. 29) that this group of rats was more erratic than any other group, being jerky and irregular in their movements. It is probable that this statement applies not to the group as a whole, but only to these six abnormally poor rats.

No significant difference exists between the 25- and 65-day rats. The difference between the averages is only .3 of a trial and the medians are the same. Between the 25 and 200 day rats there is a difference of 12 trials, $P.E.D = 3.8$.¹ The difference between the average is only three times the $P.E.D$, indicating a low reliability. If medians are used (a better measure in view of the extreme deviations in one direction) there is a difference of only two. The $P.E.Med$ of 4.64 actually exceeds the difference between the medians! There is a difference of eleven trials between the averages for the 65- and 200-day rats ($P.E.D. = 3.91$), a difference which is only 2.8 times the $P.E.D$. This method of comparison presupposes normal distributions. The distribution for the 200-day group becomes normal only with the omission of the six very poor rats. The difference between the averages then becomes two ($P.E.D = 2.0$) which is as large as the $P.E.D$. In view of these facts it appears that the monograph yields negative results. No significant age differences are shown.

Basset's monograph can be approached in the same way. Two groups of rats (control and inbred) were compared. The average time for each of the one hundred days is given. Measures of variability of each group for each trial are not given. It is impossible, therefore, to determine the significance that attaches to the small differences between the averages for the two groups of rats in any or all of the trials. Further, these differences are probably not significant because of the presence of *two* rats among the inbred group who failed to learn in one hundred days and hence tended to raise the average for this group at all stages of learning. This criticism applies with the same force to the data for relearning.

¹ The probable errors here presented were calculated from Hubbert's data by the reviewer.

The anatomical data show the relative brain weights (brain weight in relation to body length). The differences are small and as no measure of variability is given it is impossible to determine the significance of the differences.

The inbred curve for relearning is slightly above and is slightly more irregular. This difference was probably caused by two inbred rats who failed to relearn. It is doubtful if the curves represent real group differences.

It is found, in roughly working out the medians and quartiles of the distribution according to the number of days required to learn and relearn, that there is a difference in favor of the control rats of only five days while the probable error for each median is rather large (8.5 for the controls and 11 for the inbreds). Further, the distributions for the two groups are practically the same, except that four inbred and one of the control rats are exceptionally poor. Did these four inbreds and the one control rat also have exceptionally smaller brain weights? This question cannot be answered by reference to the data.

An interesting analysis (incidentally unfavorable to Basset's own thesis) of the inbred group is made. On the whole the seven rats belonging to the seventh generation were somewhat inferior to the fourteen sixth generation rats, although the anatomical data shows the seventh generation to have the greater relative brain weight! The data for the two generations show slight differences that have little or no significance because of the variabilities involved.

In addition to the statistical criticism it seems that a more direct method of showing the relationship could have been used. The 42 rats could have been ranked according to learning ability and according to relative brain weights. Coefficients of correlation would then have shown whether the relationship was positive, indifferent or inverse.

As the data are presented and interpreted it seems that no generalization can be made. This is not equivalent to saying that a positive relationship between learning ability and relative brain weight does not exist—merely that such a relationship is not demonstrated.

Ulrich's data are especially significant and positive. The absence of overlapping of the distributions makes it unnecessary to criticize the failure to use the measures of variability and the tests

of the reliability of the differences of averages which were so essential for an evaluation of Hubbert's and Basset's data. That distributed effort is more economical than concentrated effort in learning the maze is clearly demonstrated, although it is doubtful whether there is a significant difference between the three-trial-a-day group and the five-trial-a-day group.

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THE PREFERENTIAL USE OF THE HANDS IN MONKEYS WITH MODIFICATION BY TRAINING AND RETENTION OF THE NEW HABIT

During the early part of 1915 the observations here reported were made in the psychological laboratory at Saint Elizabeth's Hospital as a part of a more extensive study of the readiness with which instinctive activity can be inhibited in monkeys. The object of this group of observations was (1) to add some data to that already obtained on the tendency towards a predominant use of the right or left hand in monkeys, (2) to ascertain the readiness with which such instinctive or habitual activity can be modified and (3) to test the permanence of such modification.¹

Six *Macacus rhesus* monkeys were used.² *A*, *B* and *F* were large males, *C* was a young female and *E* and *D* were young males. So far as is known none of these animals had been used previously for experimental purposes. The observations were always made in the morning before feeding and while the animals were in cages that have been described by Franz.³ The use of the hands was observed in three different situations.

Situation 1.—Two pieces of food were placed simultaneously upon a small shelf just outside the large meshed wires of the cage. A piece of food was put near each end of the shelf and after both pieces were grasped the monkey was chased away from the wire. After the food was eaten the next two pieces were arranged. A record was kept giving the number of times each hand was used.

¹ For references to previous work in this field see: K. S. LASHLEY, Modifiability of the Preferential Use of the Hands in the *Rhesus* Monkey, *J. of Animal Behav.*, 1917, 7, 178-186.

² These animals were obtained by Dr. Shepherd Ivory Franz with a fund granted by the Carnegie Institution of Washington, and acknowledgment of the assistance is here made.

³ S. I. Franz, Observations on the Preferential Use of the Right and Left Hands by Monkeys. *J. of Animal Behav.*, 1913, 3, 140-144.

One piece was usually put in the mouth before the second was taken. In this situation the following results were obtained. *A* showed an exclusive use of the right hand in 324 trials. *B* showed a very marked preferential use of the right hand, using it 399 times in 408 trials and *C* showed a definite preferential use of the left hand, using it 264 times in 351 trials. *D*, *E* and *F* used either hand readily, *D* tending to use the left slightly more often than the right and *E* and *F* showing a slightly greater total use of the right hand. (See Table I.)

Situation 2.—One piece of food was placed in the center of the shelf. This situation was adopted in order to further test *D*, *E*, and *F*, for in the preceding situation the two pieces of food were occasionally grasped almost simultaneously or else in quick succession, the second hand being used before the first piece of food had been placed in the mouth. One hundred trials were given to each monkey and the same ambidexterity was found, although in this situation all three monkeys used the left hand more often than the right. (See Table I.)

TABLE I

PREFERENTIAL USE OF THE HANDS OF THREE SITUATIONS: I, TWO PIECES OF FOOD ON SHELF; II, ONE PIECE OF FOOD ON SHELF III, ONE PIECE OF FOOD IN EXPERIMENTER'S HAND.

Monkeys.....	<i>A</i>		<i>B</i>		<i>C</i>		<i>D</i>		<i>E</i>		<i>F</i>	
	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.	R.	L.
Situation I.....	324	0	399	9	87	264	83	132	128	96	116	84
Situation II....	..	..	..	..	..	..	28	72	48	52	35	65
Situation III....	100	0	90	10	10	202	69	131	11	189	33	167
All trials.....	424	0	489	19	97	466	180	335	187	337	189	316
Percentages....	100	0	96.3	3.7	17.2	82.8	39.9	65.1	35.7	64.2	36.8	63.2

Situation 3.—In this group of trials one piece of food was used but held by the experimenter in such a way that the monkey was obliged to reach up for it. The attempt was made to hold it so that it would appear equally accessible to either hand, *i. e.*, directly in front of the animal and at a level several inches above his head as he sat in a crouching position. Each monkey was given 200 trials with the exception of *A* and *B*, who gave in 100 trials practically the same result as in Situation I. *A* showed exclusive use of the right hand and *B* used the right hand 90 times in 100 trials. *C*'s tendency towards left-handedness became still more prominent in this situ-

ation. She used it 202 times out of 212 trials. On one occasion she used both hands simultaneously. *D* used the left hand nearly twice as often as the right. On two occasions he used both hands simultaneously. *E* and *F*, now showed a very definite preference for the use of the left hand, *E* using it 189 times and *F* 167 times in the 200 trials.

Period of Training.—*A*, *B* and *C* were used first. *A* and *B* were trained to use the left hand and *C* to use the right hand. The food was offered as in Situation 3 but when the attempt was made to grasp it with the wrong hand it was held tightly and withdrawn. A few seconds later it was again offered. Each monkey was given 125 trials before feeding on five successive days. Each of these monkeys tried repeatedly to grasp the food with the accustomed hand before using the other. *A* made 26 attempts to take the food with his right hand before using the left and although he was very hungry he sometimes ceased trying to obtain the food for several minutes at a time. He occupied forty-five minutes in making the 26 trials, but after once using the left hand he learned during the next eighty-eight trials to use it exclusively and on the following four days continued to use it without making a single error (see Fig. 1). *B* made 40 attempts to use the right hand before he tried the left and then during the next 77 trials learned to use the left hand, although he made an occasional error until the fifth day, when in 125 trials he used the left hand exclusively. *C* made 24 attempts to grasp the food with the left hand before using the right, but then showed the same rapid learning during the first day. On the second and third days she made a few errors but on the fourth day she used the right hand exclusively. *D*, *E* and *F*, were then trained to use the right hand. These monkeys were given 25 daily trials before feeding instead of 125. *D* tried 11 times before using his right hand and made 22 errors on the first day. On the second and third days he made 21 errors and on the fourth day 8 errors. On the fifth and sixth days there were only two errors. *E* made 25 failures the first day, 23 on the second and 18 on the third. On the fourth day there were only two. This monkey made an occasional error as late as thirty days after the beginning of the training, although there was one period of eight days during which he made no error.⁴

⁴This was the most timid monkey of the six and it is of interest that the poor results on the eighth day (see Fig. 1) followed a severe fright. The monkey had escaped from the cage and was chased for some time before being caught in the experimenter's hands. He had not been handled previously and his squealing seemed to indicate terror.

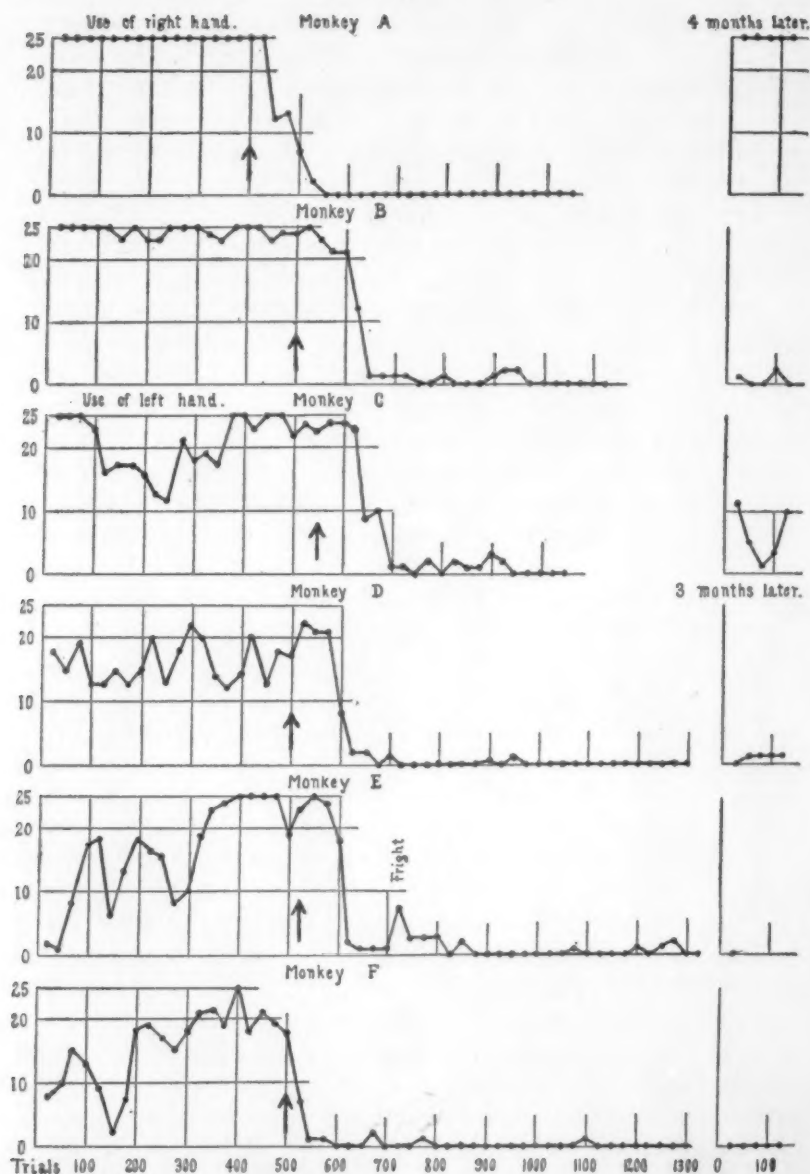


FIGURE 1. The ordinates represent the number of times that the preferred hand was used in each successive 25 trials. With *A* and *B* this was the right hand and with the others it was the left hand. The abscissae represent the number of trials grouped by 25. The arrows mark the beginning of the period of training to use the other hand. The late effect of training is also indicated.

F, who was the most ambidextrous monkey, showed the quickest learning. After the first day he only made an occasional error. The error on the eleventh day immediately followed a sudden noise made by a child just outside the window of the basement in which the experiments were conducted. The monkey turned his head suddenly towards the window and extended his left hand for the food instead of the right.

Retention of the Acquired Habit.—Four months after the end of their training *A*, *B* and *C* were tested as in Situation 3. During the interval the animals were used in another set of observations and the conditions of this experiment were not repeated. *A* showed a complete reversion to his original right-handedness, *B* showed a very good retention of the acquired left-handedness, making only three errors in 125 trials. *C* made 30 errors in 125 trials. *D*, *E* and *F* were tested three months after the end of their training and all showed very good retention of the acquired habit. *D* made four errors in 125 trials, *E* made one error in fifty trials and *F* made no error in 125 trials.

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